EMCal Optical Sensors, Readout Electronics, DAQ and Trigger WBS 1.07/1.08

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EMCal Internal Review

20-Aug-2015

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EMCal Electronics Design Concept

- Minimize custom ASICs -> off the self components
- Same optical sensor for EMCal and HCal
- Similar readout for both EMCal and HCal
  - Continuous digitization of wave forms
  - Trigger primitives for Level-1 trigger
  - High DAQ rate, ~15KHz
- Minimize On-Detector power/heat load
- Use PHENIX DAQ
  - DCM-II
  - Event Builder
  - Data Logging
  - Monitoring
- Common biasing and low voltage systems

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Optical Sensors Reference Design

– Silicon Photomultiplier, SiPM or MPPC

– High gain, ~10^5

– Dynamic range set by number of microcells

– Immune to magnetic fields

– Relatively inexpensive, ~$10 in large quantities

– Reference device: Hamamatsu S12572

- 15 μm^2 pixel size

- 40K microcells

- ~25% Photon Detection Efficiency (PDE)

- Spectral response: 320-900nm

– Potential concerns

- Temperature dependence

- Radiation effects

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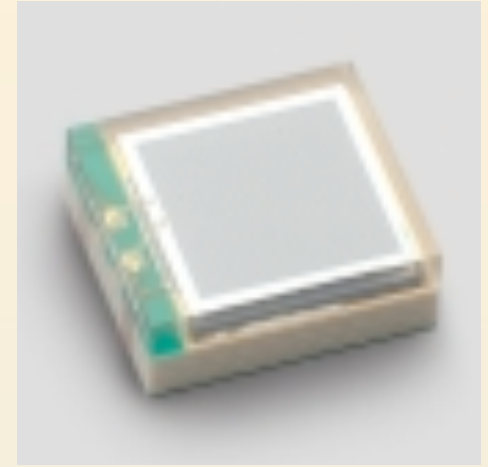
Temperature Dependence

- SiPM gain is set by the overvoltage applied to the device:
  - $V_{op} = V_{br} + V_{ov}$
- Temperature dependence:
  - ~10 %/^{0}C
- Local thermistor to monitor temperature
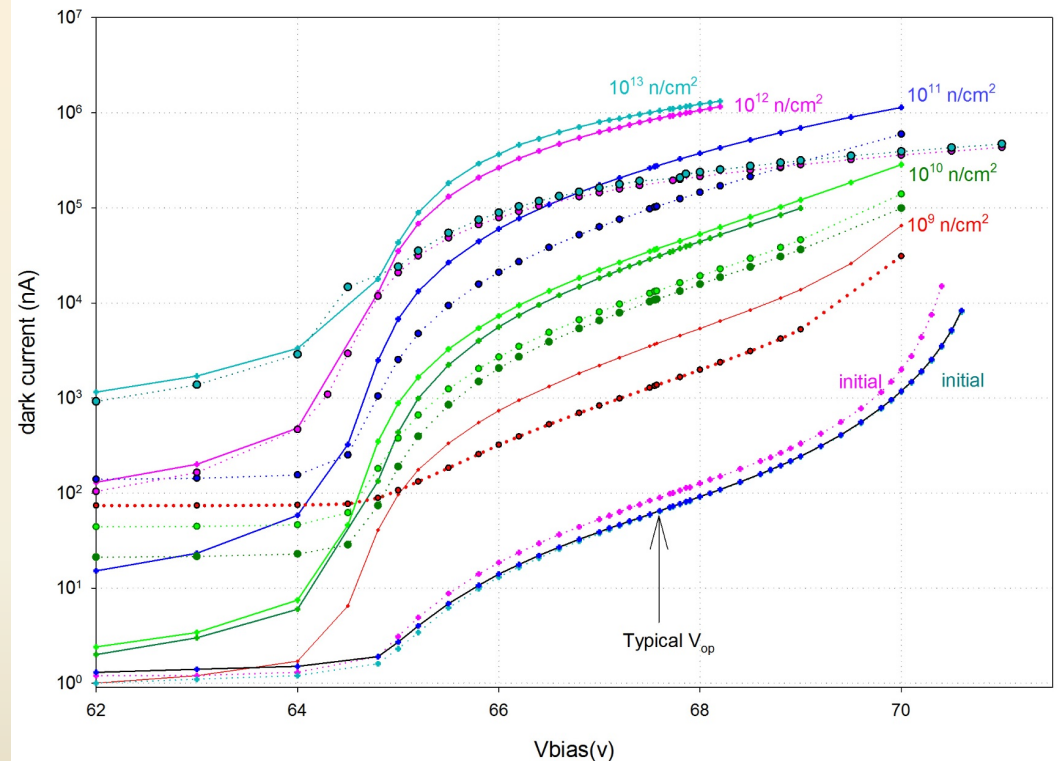- Positive feedback loop will be used to adjust the voltage to compensate for temperature fluctuations
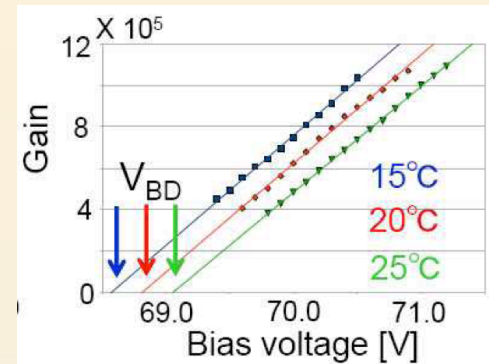
Minamino, Akihiro at al.
"T2K experiment: Neutrino Detectors"
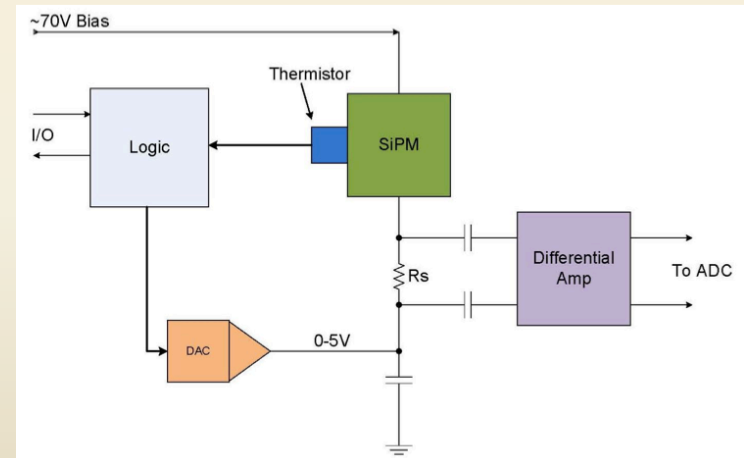
Radiation Effect

- **Displacement damage due to neutrons- Increased leakage current**

- **Study the effects of neutron damage at:**
  - LANSCE (LANL)
  - LENS (Indiana Univ.)
  - PHENIX IR
  - BNL Instrumentation

Dark Current vs Bias Voltage

- **Measurements taken at LANSCE (Dec 2014)**
  - 3 pixel sizes: 10μm, 15μm and 25μm

- **Measure dark current before and after irradiation**
  - Integrated flux: 7.2×10^{10} n/cm^2 (E > 10MeV)
  - Corresponds to ~ 3 years sPHENIX running.

- **Dark current increase @ V$_{op}$:**
  - 10μm^2: 70nA -> 95μA
  - 15μm^2: 68 nA -> 240μA
  - 25μm^2: 68 nA -> 750μA
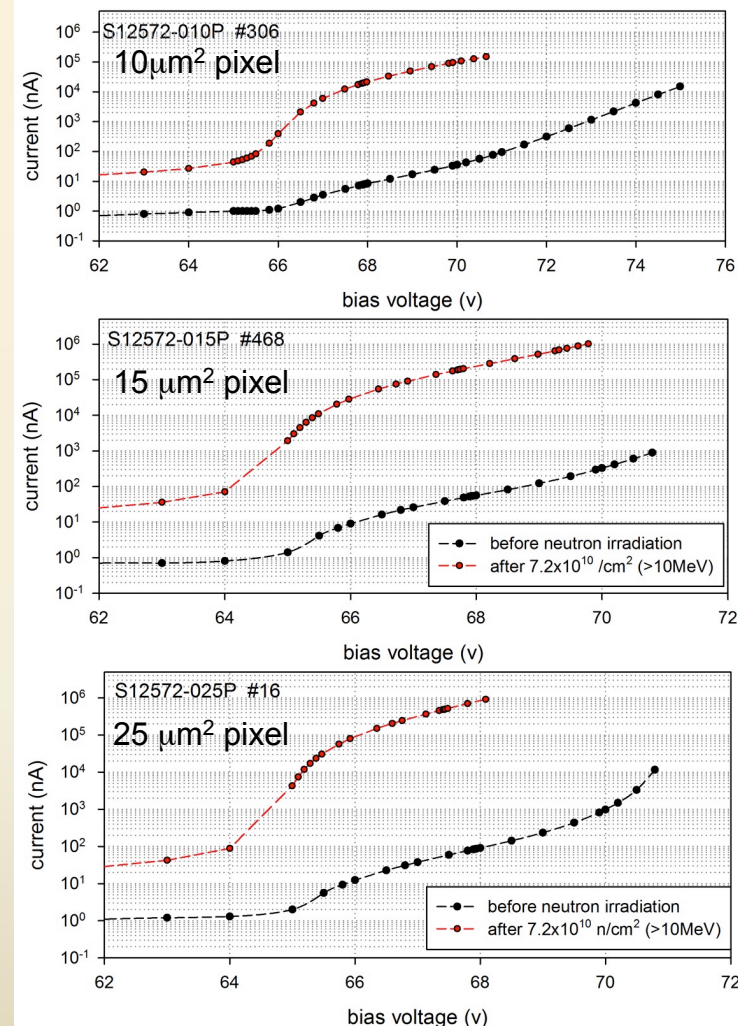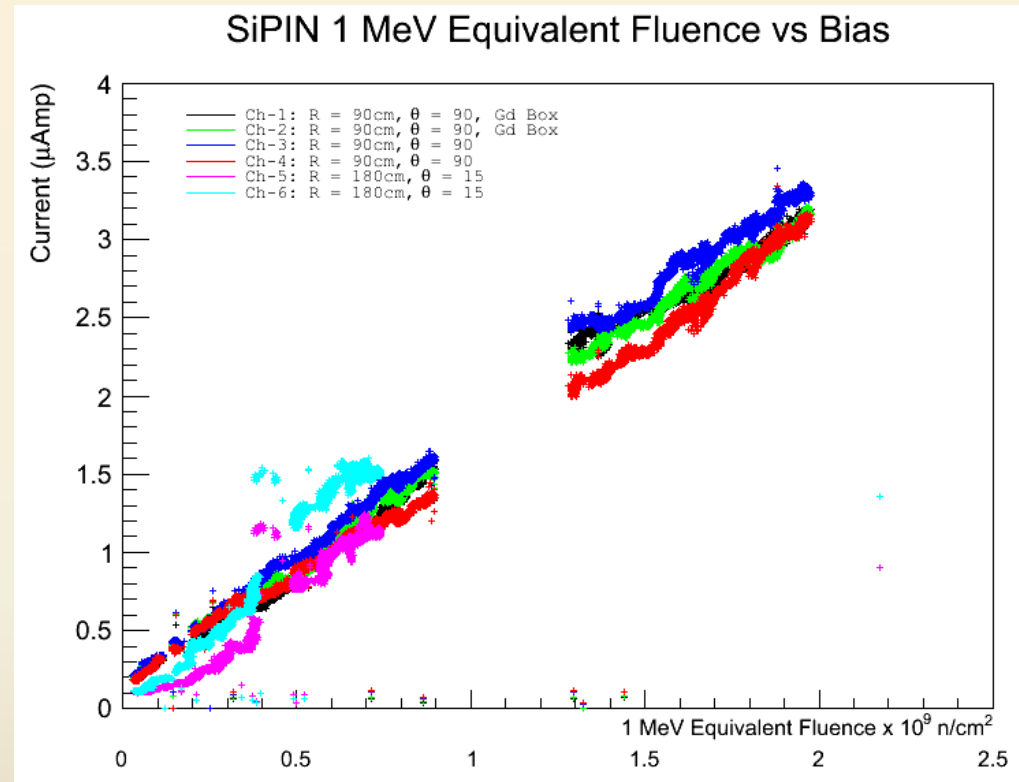
Leakage Current and Signal Response

- ## Increasing leakage current
  - Broader pedestal
  - Reduced signal-to-noise
- ## STAR measurements: RUN15
  - FMS Upgraded to use SiPMs, $25\mu m^2$ pixel
  - Observed leakage current increase as a function of time
  - Look at MIP response as a function of time
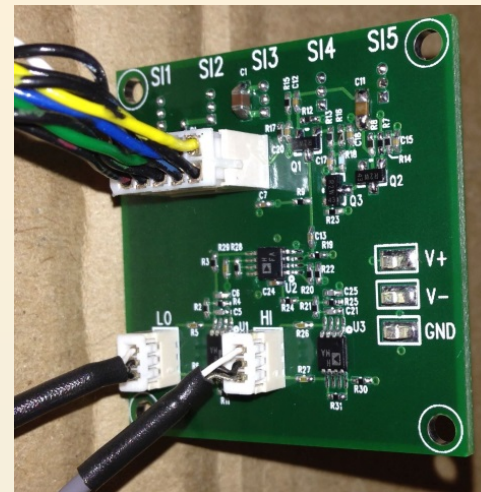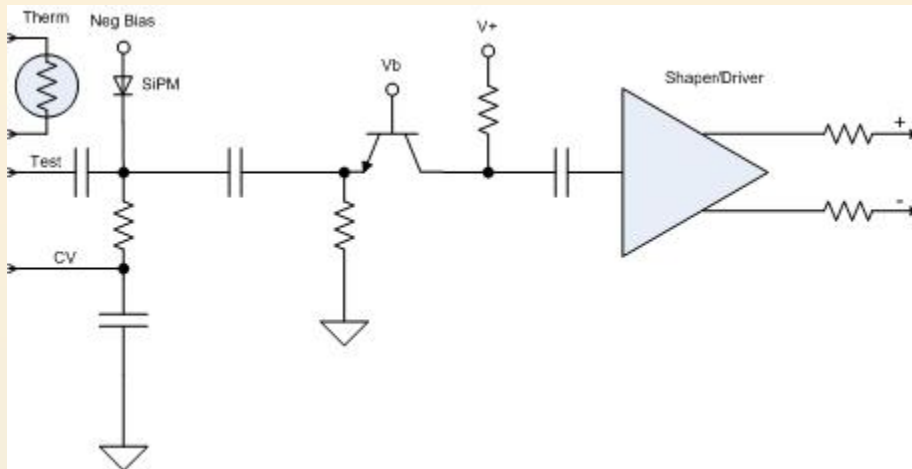 - No observable shift in MIP peak

STAR Measurements
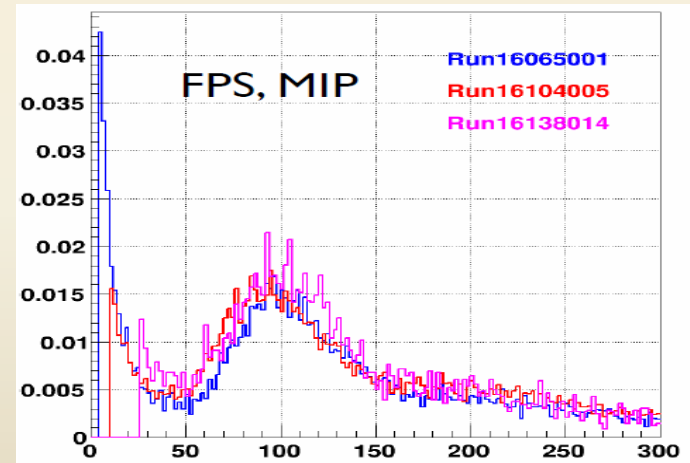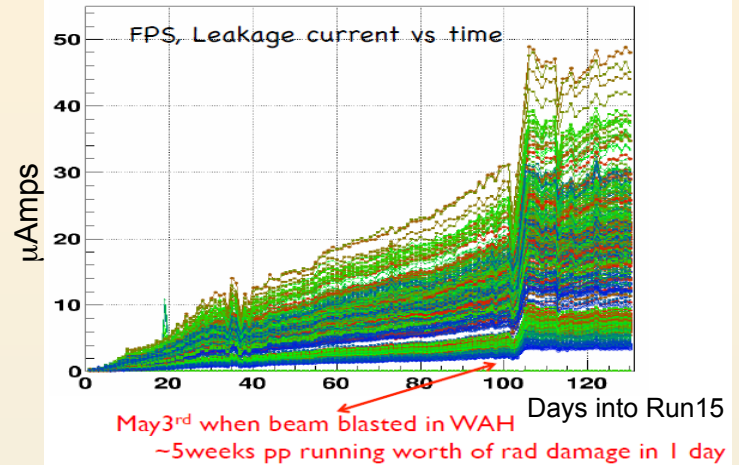
PHENIX IR Measurements

- 6 SiPMs ($25\mu m^2$ devices)
- Devices located at 2 locations:
  - 90cm from IP at $\Theta = 90^0$
  - 180cm from IP at $\Theta = 15^0$
- Measure current at fixed voltage May/June 2015
- Use CERN RadFETs to measure 1MeV neutron equivalent fluence
- We expect few 10^{10} neutrons/cm² per run

SiPIN 1 MeV Equivalent Fluence vs Bias

Ch-1: R = 90cm, θ = 90, Gd Box
Ch-2: R = 90cm, θ = 90, Gd Box
Ch-3: R = 90cm, θ = 90
Ch-4: R = 90cm, θ = 90
Ch-5: R = 180cm, θ = 15
Ch-6: R = 180cm, θ = 15

Current (μAmp)

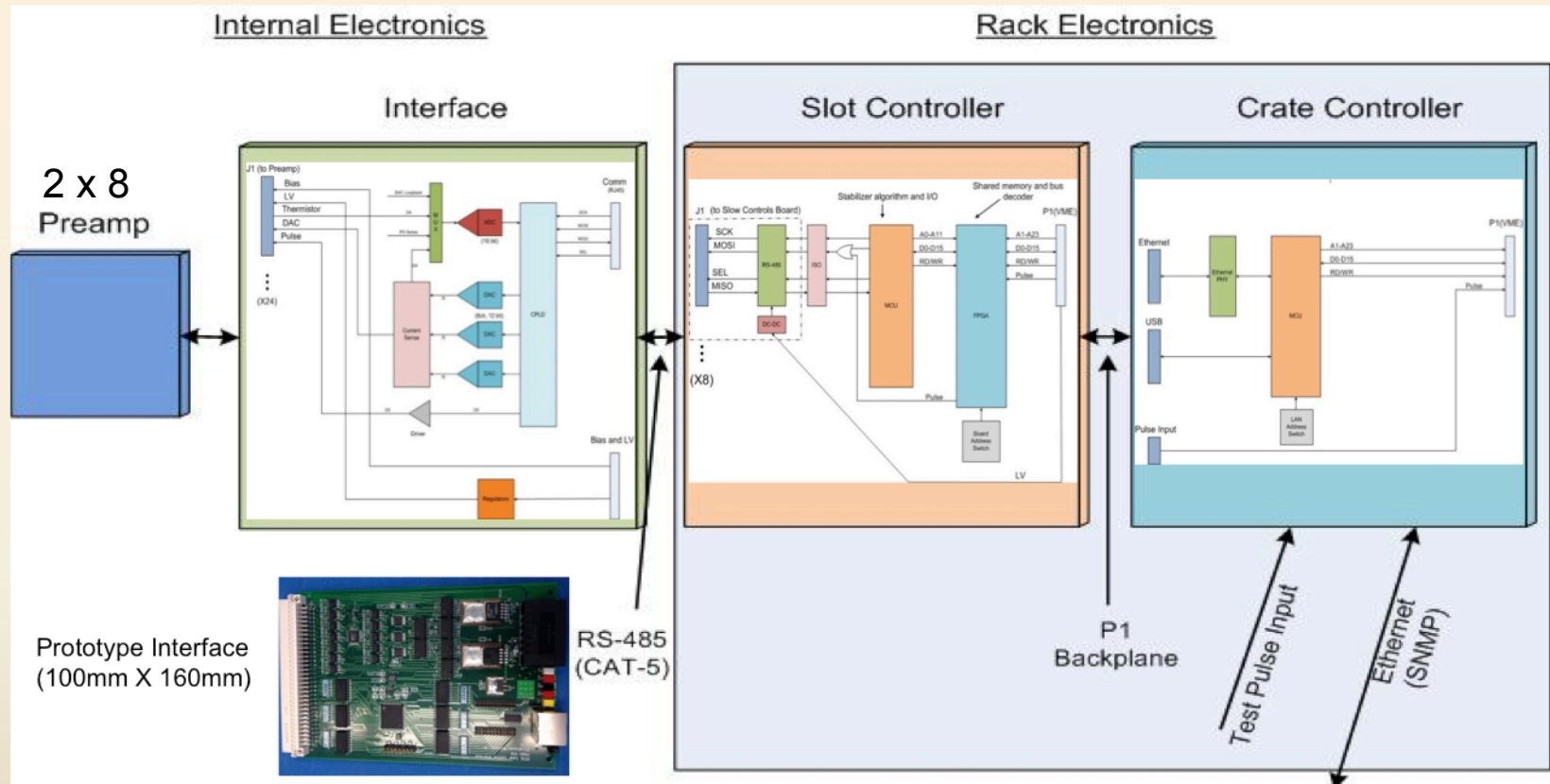1 MeV Equivalent Fluence x 10^9 n/cm²

Preamp Circuit

- *Local thermistor for temp monitoring.*
- *Control voltage input for trimming bias +/- 2.5V.*
- *Charge injector for signal test.*
- *Differential multiple-feedback filter/driver with 30nS peaking time for 65MHz ADC sampling.*
- P_D:
  - *CBA ~ 80mW*
  - *Buffer/Amp ~ 50mW*
  - *Shaper/ Driver ~ 120mW*
 - P_{tot} ~ 250mW

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# Front End Electronics Overview

sPHENIX DAQ Concept

- ## Waveform digitization
  - Located near detector
  - 65MHz digitization rate
  - 14 Bit ADC
  - Form local trigger primitives for Level-1 trigger
  - Identical for EMCal and HCal.

- ## Take advantage of PHENIX hardware
  - DCM-IIs: High speed readout, ~15KHz
  - PHENIX Event Builder
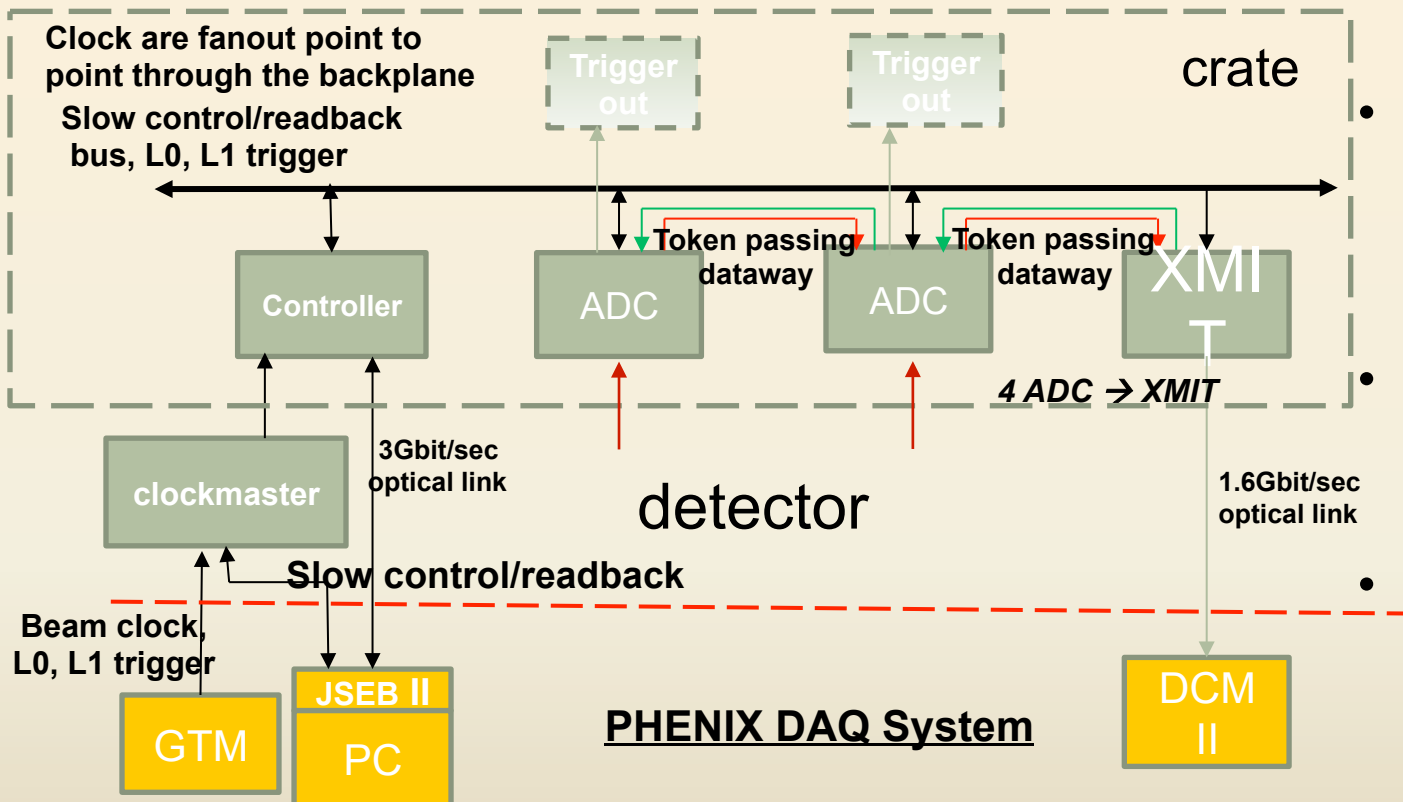 - PHENIX Timing System (MTM/GTM/GL1)

DAQ Overview
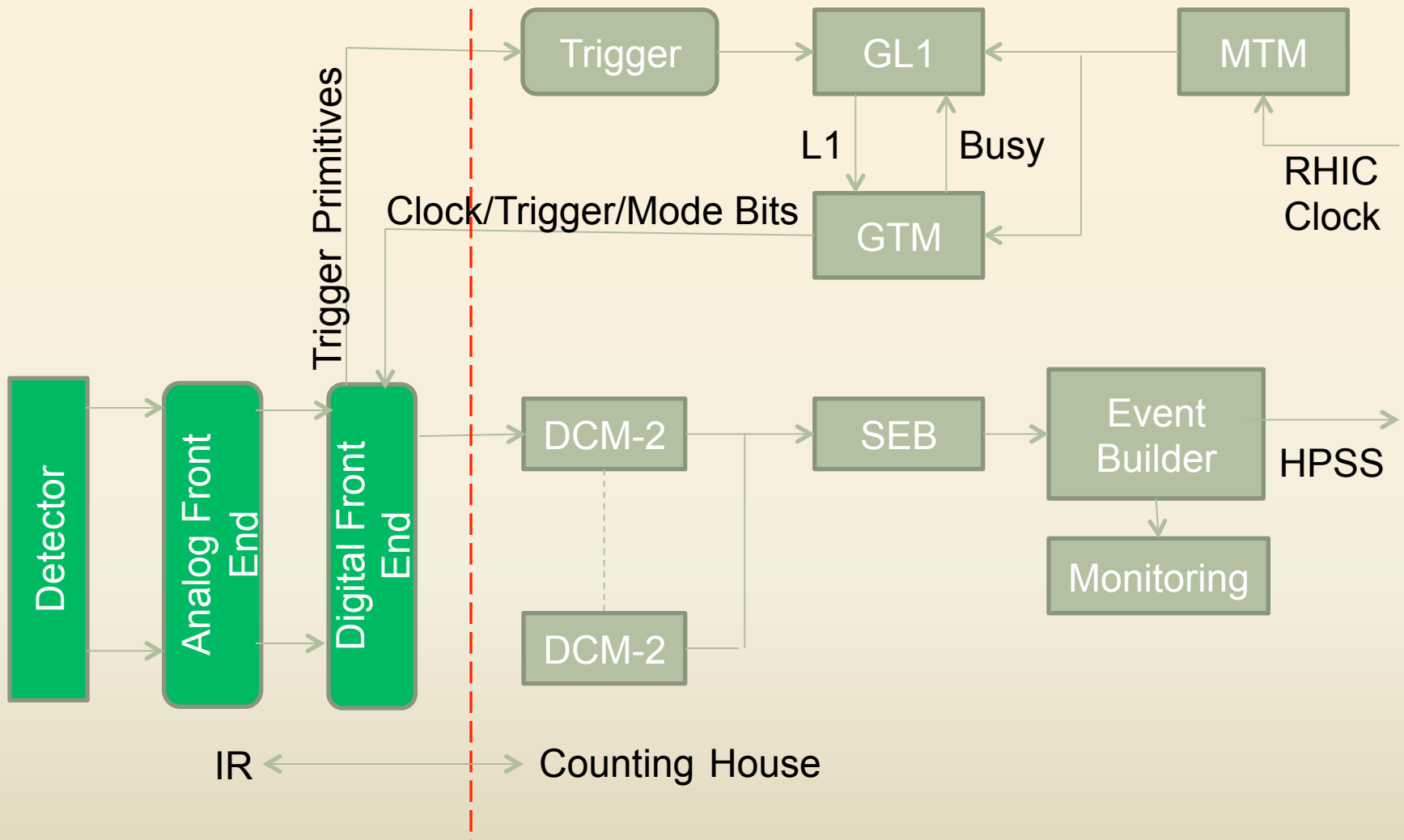
DIgitizer System

- Based on PHENIX HBD design
- 14 Bit ADC @ 65 MHz
- 64 channels per board
- Trigger Primitives based on 2x2 tower geometry
- First R&D prototypes are in fab with testing fall of 2015
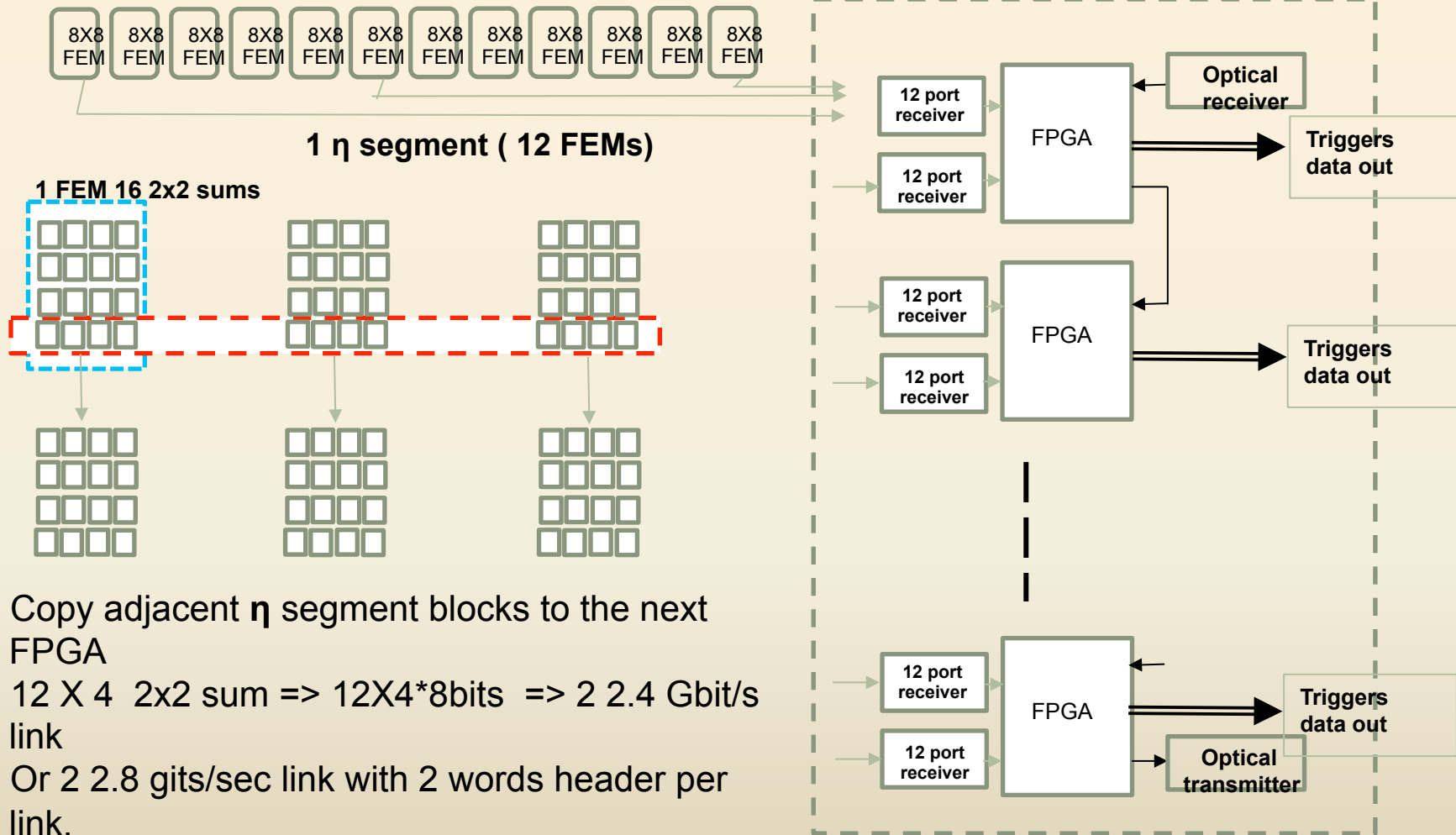- Should be available for 2016 beam test
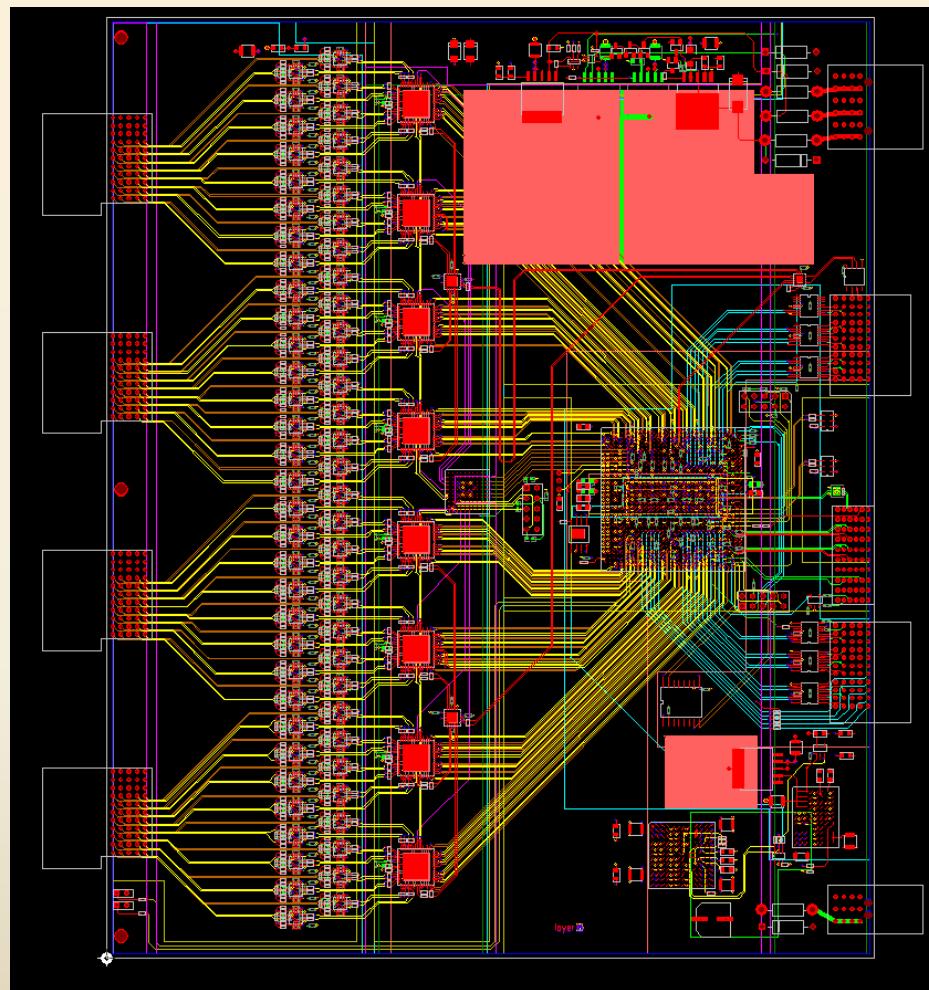
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sPHENIX Digitizer System

- Crate based system
- Differential signals from on detector eletronics
- Generate L1 Trigger primitives
- Send digitized data out when L1 request received

EMCal Trigger

8X8 FEM 8X8 FEM 8X8 FEM 8X8 FEM 8X8 FEM 8X8 FEM 8X8 FEM 8X8 FEM 8X8 FEM 8X8 FEM 8X8 FEM 8X8 FEM

1 η segment (12 FEMs)

1 FEM 16 2x2 sums

12 port receiver

12 port receiver

FPGA

Optical receiver

Triggers data out

12 port receiver

12 port receiver

FPGA

Triggers data out

12 port receiver

12 port receiver

FPGA

Triggers data out

Optical transmitter

- Copy adjacent **η** segment blocks to the next FPGA
- 12 X 4 2x2 sum => 12X4*8bits => 2 2.4 Gbit/s link
- Or 2 2.8 gits/sec link with 2 words header per link.

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Calibration and Monitoring

- Preamplifiers have built in charge injection.
  - System testing and monitoring
  - Electronics calibration
- LED Pulsar system system built into preamp boards
  - Pulsed through slow control system
  - Illumination of light guides
  - Experience in PHENIX: MPC, ZDC…
- Gain compensation by controlling SiPM overvoltage (Temperature stabilization circuit)
- Ultimate calibration offline using π^0 peak PHENIX EMCal
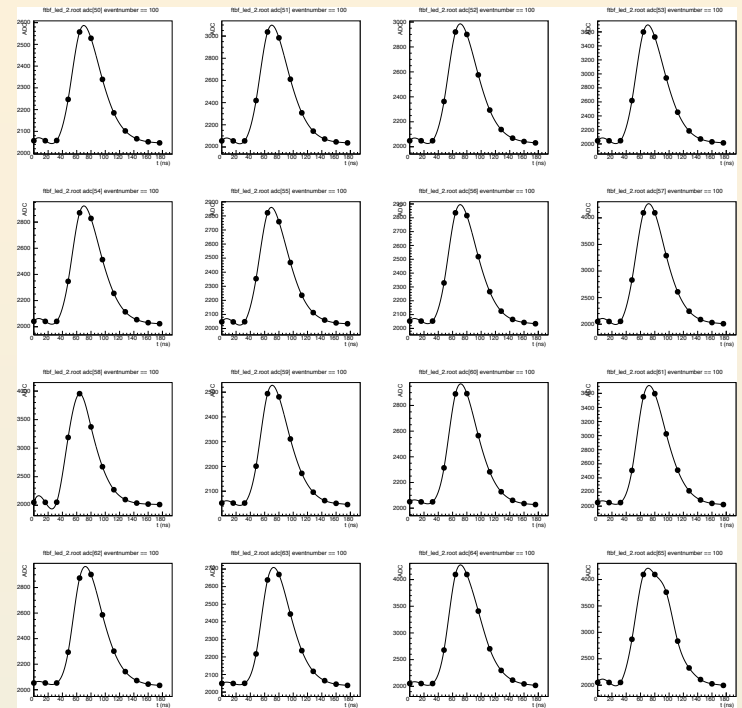
LED signal observed in
EMCal test beam prototype
Using HBD readout electronics

Issues and Concerns

- The electronics (WBS 1.7) had internal review in March 2017 and recommendations are being addressed
- Reference sensor is the SiPM
  - Temperature dependence
  - Radiation effects
- R&D work is in progress to design and test a common base amplifier for the upcoming beam test.
  - Gain scale
  - Signal-to-Noise
- R&D work is in progress for the next generation digitizers
- Reference design for trigger system is being developed based on 2x2 tower sums.
- Calibration and monitoring systems being developed.
- System integration and assembly

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